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Chemical and Bacteriological Quality of Pasture Runoff

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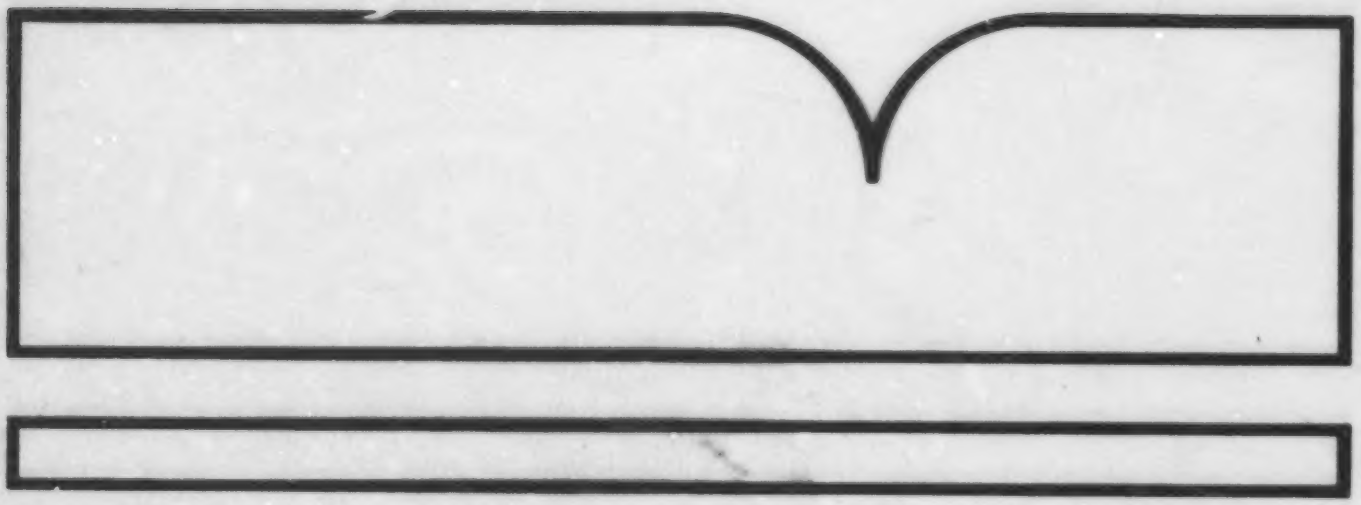

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16. ABSTRACT

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Chemical and bacteriological quality of pasture runoff

J. W. Doran, J. S. Schepers, and N. P. Swanson

ABSTRACT: Natural background characteristics and grazing cattle both influence the chemical and bacteriological quality of pasture runoff in south central Nebraska. The chemical quality of runoff from unstocked grassland was poorer than that from grazed pasture. The chemical quality of pasture runoff, which was better than runoff from cultivated cropland and urban areas, was within recommended water quality criteria. Cattle grazing increased fecal coliform (FC) counts 5- to 10-fold; however, FC counts in rainfall runoff from both grazed and ungrazed pasture, which were comparable to FC counts in runoff from cropland and urban areas, exceeded the water quality criterion of 200 organisms per 100 milliliters more than 90 percent of the time. The FC/fecal streptococci (FS) ratio of runoff from both grassland and ungrazed pasture was characteristic of wildlife feces, suggesting that the natural background level for bacteriological inputs may be large. Recommended bacteriological water quality criteria may be inappropriate for characterizing pasture runoff and other nonpoint sources of potential pollution.

ENVIRONMENTAL impacts of runoff from agricultural land are difficult to study because of the diversity of nonpoint-source pollution. An estimated one-third of the water pollutants in the United States come from nonpoint sources. Animal wastes are often cited as a major source of pollution because more than a third of the land in the continental United States is grazed by livestock. This grazed land receives an estimated 50 percent of all livestock wastes (22).

The effects of livestock grazing operations on the quality of runoff waters depend upon many management and climatological factors. Consequently, the effects are not well defined. Good plant residue cover generally reduces runoff and soil loss and minimizes the potential for nutrient movement from grazing land into streams and rivers (*14, 19, 27*). Little attempt has been made to quantify that proportion of potential pollutants in runoff attributable to a natural, ungrazed environment.

Counts of selected bacterial-indicator organisms traditionally have been used to monitor water for fecal contamination. Identifying specific nonpoint sources requires that the indicator organism be specific for a given source of pollution, for example, livestock. The measurement of fecal coliforms (FC) is reportedly the most reliable indicator of the fecal pollution of water, but this parameter does not identify the source (*9, 10*).

Analysis of water for both FC and fecal streptococci (FS) has been suggested as a method of determining whether fecal contaminants are from human or other warm-blooded animals (7). Water with a FC/FS ratio greater than 4 usually indicates pollution from domestic wastewater. A ratio less than 0.7 indicates contamination from nonhuman animal wastes. The FC/FS ratio in fresh feces of domestic livestock (cattle, sheep, and poultry) ranges from 0.10 to 0.42. That for wildlife (including rabbits, field mice, chipmunks, and birds) ranges from 0.001 to 0.04. The FC/FS ratio thus seems useful in determining the relative contributions of cattle and wildlife to rainfall runoff from grasslands.

The major objective of our research was to determine the chemical and bacteriological characteristics of runoff from a pasture supporting a typical cow-calf operation in the Great Plains. These characteristics of pasture runoff could then be compared with runoff water quality from other nonpoint sources.

Site description and methods

The 43-hectare (106-acre), fenced pasture was located at the Roman L. Hruska U.S. Meat Animal Research Center near

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Clay Center in south central Nebraska. Average annual precipitation in this area is 665 millimeters (24.7 inches). The area was cultivated farmland from the 1880s until 1942. It then became part of a U.S. government ammunition depot and was planted to warm- and cool-season grasses. In 1967 the property was transferred to the U.S. Department of Agriculture and from that time until 1975 was used as unimproved bromegrass (*Bromus inermis* Leyss) pasture for limited cattle grazing.

The pasture is south facing and drains a watershed of 32.5 hectares (80.3 acres). Slope in the watershed generally ranges from 0 to 3 percent, but small areas adjacent to the grassed drainageway range from 3 to 11 percent.

We used a small area [0.11 hectare (.27 acre)] adjacent to the main flume, from which livestock was excluded, to establish background levels of runoff water quality for ungrazed conditions. A discrete runoff area (control) was maintained using a steel border.

Good pasture management was practiced for a seasonal grazing cow-calf operation. Grass productivity was increased by annual fertilization with 73.9 kilograms of N per hectare (66 pounds per acre) as ammonium nitrate (NH_4NO_3) in late March or early April. No fertilizer was applied in 1979. Animal stocking rates were maintained between 44 and 57 animal units per month during the grazing season from April through November. This rate is considered typical of a well-managed, seasonal grazing operation on improved pasture in this part of the county. We determined rotational grazing periods by rainfall distribution and the quantity and quality of pasture grass. The grazed pasture was left unstocked in 1979 to permit determination of runoff water quality without cattle.

From 1975 through 1978, vegetation on the control area was mowed periodically and removed to simulate the hydrology of the grazed pasture. During 1979, the control area was not mowed. The control area was not fertilized, except in 1977, when it received NH_4NO_3 at the same rate (73.9 kilograms N per hectare) as the main pasture.

Runoff from the grazed pasture was diverted through a 0.91-meter (3-foot) H-flume at the south end of the pasture. We measured runoff flow and peak discharge with a water-stage recorder on the flume. The control area was similarly equipped, except the flume was smaller [0.3 meter (1 foot)]. We measured rainfall intensity, duration, and amount with both a weighing rain gauge and a standard gauge near the south end of the pasture.

Water samples (usually 3 liters) were collected for chemical analyses during each precipitation event from both the main pasture and control area using a programmable, rotating-arm sampler (*20*). Samples were taken at 5-, 10-, 15-, 20-, and 40-minute intervals after runoff began, and at 60-minute intervals for the next 9 hours. Samples were stored at 4°C until analyzed. Schepers and Francis (*17*) provided details of the chemical analyses.

We calculated average flow-weighted concentrations of each chemical constituent for a given event by weighting the concentration of each sample proportional to the flow rate at the time it was collected. In this way, samples collected at extremely high or low flow rates more appropriately influence the average flow-weighted chemical concentration. This gives a better indication of the water's potential effect on the environment. To calculate the average concentration over a number of events, we similarly weighted the average chemical concentration of each constituent for each event according to the total volume of runoff for that event. Hereafter, we refer to this as the event-weighted average.

We collected surface runoff samples manually for bacteriological analyses from flume discharges in sterile, 1-liter polypropylene bottles. Samples were collected at intervals representing the early, middle, and late segments of each runoff event and stored at 4 to 5°C until analyses could be completed. All samples were processed and incubated within 24 hours after sampling. Bacterial counting procedures for total coliforms (TC), FC, and FS were standard methods outlined by the American Public Health Association (*1*). Doran and Linn (*6*) gave details of these procedures.

Table 1. Precipitation, runoff, and cattle stocking rate on a test pasture, Clay Center, Nebraska, 1975-1979.

Year	Precipitation* (mm)	Runoff: Grazed Pasture (mm)	Runoff: Control (mm)	Stocking (Au/m)†
1975	677	-	0.0	22.4
1976	561	0.2	0.0	38.7
1977	1,020	105.4	225.6	37.0
1978	567	36.7	40.5	49.5
1979	731	-	-	0.0

*About 9 percent of the precipitation occurred as snow.
†Average monthly stocking rate (animal units) during the 8-month grazing season (April-November) for the 43-hectare pasture.

Table 2. Chemical characteristics of pasture runoff, Clay Center, Nebraska, 1976-1978.

Chemical Constituent	Average Concentration (ranges): Grazed Pasture, No Livestock	Grazed Pasture, Livestock Present	Control Area
	mg/l		
Snowmelt*			
$NH_4^+ - N$	1.40 (0.16-2.54)		2.08 (0.14-2.83)
$NO_3^- - N$	1.30 (0.14-3.49)		2.57 (0.53-5.68)
TKN	6.64 (3.29-20.00)		7.52 (3.10-11.70)
Soluble P	1.27 (0.88-2.35)		3.76 (0.78-7.47)
Total P	1.51 (0.95-2.94)		4.09 (0.80-7.42)
TOC	22.7 (15.0-79.2)		28.8 (12.3-62.8)
COD	64.9 (38.0-117.0)		84.6 (28.0-202.0)
Cl^-	4.70 (1.45-22.72)		7.32 (2.57-10.82)
Total solids	-		-
Rainfall†			
$NH_4^+ - N$	0.31 (0.21-0.76)	0.33 (0.25-2.98)	0.63 (0.39-1.14)
$NO_3^- - N$	0.29 (0.04-1.32)	0.42 (0.02-1.57)	3.31 (0.29-5.83)
TKN	4.11 (2.13-7.00)	3.33 (2.21-10.86)	9.20 (4.40-12.70)
Soluble P	0.54 (0.36-1.42)	0.80 (0.62-2.31)	4.15 (1.46-6.09)
Total P	0.92 (0.57-1.99)	1.26 (1.07-3.76)	4.72 (1.56-7.10)
TOC	19.7 (14.6-42.0)	21.9 (18.7-84.3)	44.9 (21.3-108.2)
COD	46.3 (36.0-88.4)	49.4 (41.6-274.0)	117.1 (71.5-314.0)
Cl^-	1.86 (0.78-5.19)	3.32 (2.45-16.46)	6.05 (1.09-10.44)
Total solids	118 (100-382)	179 (100-847)	182 (100-860)

*Values shown are arithmetic means.
†Values shown are event-weighted averages.

Results and discussion

Average annual precipitation for the 5-year study period was 711 millimeters (28 inches), slightly above the 10-year average [640 millimeters (25.2 inches)] for the area. The 5-year average was influenced by 1,020 millimeters (40.2 inches) of precipitation during 1977, a very wet year (Table 1). Twenty-eight measurable runoff events occurred that year, eight of which contributed 95 percent of the total

Table 3. Average annual nutrient loads in runoff from several nonpoint sources.

Runoff Areas, Locations	Management* System	Runoff Nutrient Loads (kg/ha/yr) Sediment	TKN	$NH_4^+ - NO_3^-$ N	Total P	Ortho P	Source
Pastureland							
Nebraska	Rotational grazing	196	2.8	0.78	0.69	0.38	This paper*
	Rotational grazing	290	1.9	0.25	0.19	0.07	(*13*)
Oklahoma	Continuous grazing	19-23	9.7	2.25	4.60	0.03	(*14*)
	Rotational grazing	0.2-2.0	2.1	0.75	1.30	0.03	(*14*)
	Rotational grazing	9.4	5.2	0.18	0.04	-	-†
Ohio	Rotational grazing	-	0.6-3.3	-	0.3-1.3	-	(*5*)
Minnesota	Prairie‡	-	0.8	0.26	0.11	0.03	(*21*)
Cropland							
Nebraska	Corn, soybeans, sorghum						
	Till plant	191	3.8	1.00	0.15	0.11	(*13*)
	Conventional tillage	2,566	7.8	0.96	0.16	0.08	(*13*)
Oklahoma	Wheat & alfalfa, dryland	500-2,000	5.8-6.6	2.1-3.2	2.5-2.9	0.44-1.13	(*14*)
Iowa	Corn, contour terraced	-	28-50	0.86-1.89	0.49-0.95	0.10-0.15	(*3*)
	3 years pasture, 2 years no-till corn	-	14.1	0.73	0.27	0.16	(*3*)
Forest		-	3-13	-	0.03-0.9	-	(*12*)
Urban							
Ohio	Residential and light commercial	818	10	3.64	2.8	-	(*25*)

*Average of data from 1976, 1977, and 1978, as presented in this paper.
†Crow, F. R., J. Powell, and D. Wagner. 1979. "Nonpoint Source Pollution: How Much Does a Well-Managed Rangeland Watershed Contribute?" Paper presented at the American Society of Agricultural Engineers of Southwest Branch meeting, Hot Springs, Arkansas.
‡80% of runoff resulted from snowmelt.

runoff for the year. Average annual precipitation for 1976 and 1978 was below the 10-year average. Because of dry pasture conditions preceding rainfalls, only three measurable runoff events occurred during 1975 and 1976. Most of the annual precipitation during the 5-year study occurred during the growing season, which is common in the Great Plains.

Chemical water quality. Table 2 shows the average concentrations of chemical components in snowmelt and rainfall runoff for 1976 through 1978. Snowmelt runoff occurred mainly in February and March and was collected manually. Intermittent frozen conditions resulted in inconsistent hydrograph data. The chemical concentrations in snowmelt, therefore, are arithmetic means and not weighted to compensate for flow rate at the time of sampling.

Although the ungrazed control was different hydrologically from the grazed pasture, these differences should have had a minimal effect on snowmelt runoff. In all cases, concentrations of chemical constituents in snowmelt runoff from the control area were 1.3 to 3.0 times greater than those in snowmelt runoff from the grazed pasture. These differences may have been due to the type and amount of plant material or wildlife activity on the two areas.

Average concentrations of nitrate nitrogen ($NO_3^- - N$), total Kjeldahl nitrogen (TKN), ortho-phosphate (soluble P), total P, total organic carbon (TOC), chemical oxygen demand (COD), and chloride (Cl^-) in rainfall runoff from the control area were 1.9 to 7.9 times greater than average values in runoff from the grazed pasture (Table 2). In general, the chemical concentrations in runoff from the grazed pasture were 1.1 to 1.8 times greater during livestock grazing than when no livestock were present. TKN seemed to be the one exception. However, when we examined these data closely, we traced this anomaly back to one large runoff event in the spring of 1978, when the average TKN concentration was 4.10 milligrams per liter. This one event represented about 60 percent of the total runoff discharged during the 3 years while livestock were not grazing the pasture. This emphasizes the need for caution in calculating an event-weighted average when one event represents a large proportion of the total runoff.

The chemical quality of both snowmelt and rainfall runoff was within recommended water quality criteria for all events but one. This rainfall runoff event occurred 1 day after the pasture was fertilized with NH_4NO_3, and the $NO_3^- - N$ and ammonium nitrogen ($NH_4^+ - N$) in runoff for this event were 12 and 6 milligrams per liter, respectively, for the grazed pasture and 26 and 10 milligrams per liter, respectively, for the control area.

Average concentrations of TKN, $NH_4^+ - N$, $NO_3^- - N$, and total P in runoff were comparable to those reported for runoff from pastureland and cropland in Oklahoma (*14*). The values from our study, however, were lower than those reported for runoff from diversified terraced and contoured corn watersheds in southwestern Iowa (*4*). The soluble P content of runoff from our pasture was somewhat higher than that in runoff from the Oklahoma or Iowa pastures and croplands.

Nutrient- and sediment-loading rates from nonpoint runoff sources are more important than concentrations in determining the potential effect on the quality of receiving waters. Table 3 shows the average yearly nutrient and sediment loads in runoff from this cow-calf pasture study. Values for nutrient and sediment loads from other nonpoint sources are given for comparison. Average yearly sediment, TKN, $NH_4^+ + NO_3^-$, and total P loads in runoff for our study were comparable to values shown for other rotational grazing operations, but lower than those for continuous grazing. The soluble P in runoff from our pasture was 10 times higher than that in runoff from the other grazing watershed studies. However, most of the nutrient loading in our study occurred during 1977 when rainfall and runoff were twice the long-term average. Sediment and nutrient loading in runoff from croplands and urban areas were higher than those from grazed pastures.

Average yearly N in precipitation falling on our test pasture between 1976 and 1978 was 12.2 kilograms per hectare (10.9 pounds/acre). Thus, more N entered the watershed in precipitation than was lost in runoff. This observation agreed with observations by Schuman and Burwell (*18*) and Loehr (*12*)—more N and P enter most watersheds with precipitation than leave them in surface runoff.

Bacteriological water quality. For purposes of discussion, we will assess the bacteriological quality of pasture runoff in terms of surface water quality criteria as recommended by the U.S. Department of Interior (*23*) and the Environmental Pro-

tection Agency (*24*). The 1968 water quality criteria are based on expected use of surface waters. Criteria for TC are 1,000 and 5,000 organisms per 100 milliliters for primary- and partial-contact recreational use, respectively. Corresponding criteria for FC are 200 and 1,000 organisms per 100 milliliters. The only bacteriological criterion retained in the 1976 water quality recommendations is the log mean value for FC of 200 organisms per 100 milliliters for recreational bathing water.

These water quality criteria were based on limited epidemiological information and were developed primarily for point-source inputs to surface water; therefore, they may not be appropriate for evaluation of nonpoint pollution. Also, agricultural runoff will be diluted further after it enters surface receiving water. Consequently, the impact of runoff on the bacteriological quality of surface water will be less than runoff concentrations suggest.

Table 4 shows the average counts and ranges for bacteriological water quality indicators for snowmelt and rainfall runoff from 1976 through 1978. In 1976 and 1978 nine snowmelt runoff events occurred. The TC counts in snowmelt runoff from both the grazed and control areas exceeded recommended water quality standards for all samples but one. FC counts in snowmelt runoff from both areas were within the 200 organisms-per-100-milliliter criterion for use in primary-contact recreation. Because TC organisms are common inhabitants of soil, whereas FC organisms are not, these results support the common assumption that FC counts are more appropriate than TC counts as an indicator of fecal contamination involving agricultural nonpoint-source inputs (*6*).

TC and FC counts in snowmelt runoff from the control area were comparable to or slightly higher than those in runoff from the grazed pasture. FS counts in snowmelt runoff from the control area were much higher than those in runoff from the grazed pasture. This relationship was also reflected by a lower FC/FS ratio in control area runoff compared with that in runoff from the grazed pasture. While we were sampling snowmelt runoff, we observed higher wildlife activity on the smaller, better protected control area, for example, numerous fecal droppings from field mice and rabbits. Increased FS counts in control-area runoff were apparently related to this greater wildlife activity.

We sampled 26 rainfall runoff events for bacteriological indicators. Counts for both TC and FC in rainfall runoff from the grazed pasture exceeded water quality criteria for 25 of 26 runoff events. The FC counts were lowest (120 organisms per 100 milliliters) in runoff during April 1978, when cattle were not on the pasture and water temperatures were low (4 °C).

TC counts in rainfall runoff from the control area were comparable to those in runoff from the grazed pasture. FC counts in rainfall runoff from the control area were 10 times lower than FC counts in runoff from the grazed pasture. Even so, FC counts in more than 95 percent of the runoff samples from the control area exceeded the recommended water quality criterion (200 organisms per 100 milliliters). FS counts in rainfall runoff from the control area averaged 3 times higher than counts from the grazed pasture. The lower FC counts and higher FS counts resulted in a lower FC/FS ratio in runoff from the control area.

Table 4. Summary of bacteriological water quality indicators in snowmelt and rainfall runoff from 1976 through 1978.

Runoff Type, Indicator	*Runoff Characteristics**	
	Grazed Pasture	*Control Area*
Snowmelt		
TC†	95,000 (7,900-330,000)	528,000 (7,000-1,700,000)
FC†	47 (0-110)	120 (0-220)
FS†	2,830 (0-6000)	93,000 (7,500-162,000)
FC/FS ratio	0.022 (<0.010-0.060)	0.001 (<0.001-0.002)
Rainfall		
TC†	562,160 (700-4,900,000)	450,100 (11,000-2,300,000)
FC†	113,700 (120-1,300,000)	13,280 (0-49,000)
FS†	342,300 (8,000-6,100,000)	1,031,600 (65,000-5,400,000)
FC/FS ratio	0.387 (0.010-4.000)	0.020 (0-0.080)

*Values expressed represent arithmetic means for 1976 through 1978; values in parentheses represent range of sample values.
†Bacterial counts expressed as organisms per 100 milliliter.

The FC/FS ratio in runoff may be helpful in distinguishing between the relative fecal inputs of cattle and wildlife. The average FC/FS ratio of 0.387 in runoff from the grazed pasture is characteristic of that of cattle feces. The FC/FS ratios were lowest (0.010 to 0.112) when cattle were off the pasture or when very few were present. The FC/FS ratios were highest (0.22 to 4.0) when the largest number of cattle were grazing (*6*). The average FC/FS ratio in runoff from the control area (0.020) is characteristic of the FC/FS ratio of wildlife feces.

Table 5 compares the bacteriological water quality of snowmelt and rainfall runoff from our study with water quality from several other nonpoint runoff sources. TC, FC, and FS counts in runoff from our study were higher than respective counts reported for runoff from other grazed grassland areas. FC counts from our study resembled those of Robbins and associates (*15*), who reported yearly mean FC counts from grazed and ungrazed watersheds in North Carolina of 30,000 and 10,000 organisms per 100 milliliters, respectively. Counts of all bacteriological indicators in runoff from our study were within the same order of magnitude as those in runoff from croplands and urban areas. FC counts in most runoff from grassland, cropland, and urban areas exceeded the water quality criterion (200 organisms per 100 milliliters) for use in recreational bathing. Also, the FC/FS ratio in runoff from many of these sources was characteristic of that of wildlife feces. Therefore, the natural background contributions to FC counts in runoff from nonpoint sources should be evaluated further before water quality criteria are used to establish water quality standards.

Water quality without grazing. Concentrations of all measured chemical constituents and FS counts in the rainfall runoff were greater from the ungrazed control area than from the grazed pasture. The hydrology of the two areas was admittedly different; only 15 runoff events were recorded on the control area, whereas 33 events were recorded on the grazed pasture. The amount of vegetational cover and wildlife activity was also usually somewhat greater on the control area. These plant and wildlife residues can serve as a source of many nutrients and microorganisms that may be considered as potential pollutants once they become a component of runoff waters.

To evaluate the effect of different vegetational cover and associated wildlife activity on the chemical and bacteriological quality of runoff from the grazed pasture

Table 5. Bacteriological water quality for several nonpoint sources of surface runoff.*

Runoff Source, Management System	Water Quality Indicator TC	FC	FS	FC/FS	FC Counts >200/100ml (%)	Source and Location
	organisms/100ml†					
Grasslands						
Bromegrass pasture, grazed†	329,000	57,000	172,000	0.022-0.387	88	This paper
Bromegrass, no cattle	489,000	6,600	563,000	0.001-0.020	64	Nebraska
Hayfields, pasture, forest	41,300	7,100	-	-	90	(*11, 12*)
Hayfield, no grazing or manure	71,000	1,070	30,000	0.002-0.132	50	Vermont
Grazed pasture‡	6,000	1,000	1,750	0.571	83	(*9*)
Bromegrass and alfalfa hayfield‡	4,000	660	4,150	0.159	82	South Dakota
Croplands						
Corn, wheat, meadow rotation	3,200	12	1,700	0.007	10-50	(*26*)
Mixed cover	8,100	1,200	8,400	0.143	50-90	Ohio
Cultivated cropland	50,000	5,400	39,000	0.138	94	(*9*)
Oats stubble‡	3,300	66	585	0.113	13	South Dakota
Fall-plowed†	145,000	130	16,200	0.008	42	
Row crops	15,800	14,300	-	-	-	(*16*) Tennessee
Urban						
Business and residential	58,000	10,900	20,500	0.531	90	(*25*) Cincinnati
Business district	106,000	21,000	34,500	0.15-0.71	100	(*8*)
Residential street gutters	146,000	23,500	76,000	0.02-0.34	75	Cincinnati
Wooded hillside	90,000	960	14,000	0.02-0.71	50	
Stormwater runoff	2,170,000	180,000	110,000	0.26-1.12	100	(*2*)
Combined stormwater and sewage	20,000,000	4,245,000	1,710,000	3.65-21.7	100	Ann Arbor and Detroit

*Median values of arithmetic means, geometric means, or median ranges.
†Rainfall and snowmelt runoff.
‡Snowmelt runoff, all others represent rainfall runoff.

area, cattle were kept off the main pasture during 1979. The last animal stocking (292 animal units) occurred in October 1978.

Table 6 shows the results of chemical runoff analyses for 1979. Concentrations of NH_4^+, NO_3^-, and soluble P in runoff from the pasture were comparable to values during the previous grazing years. Concentrations of TKN and COD were higher in runoff than in previous years. Lower concentrations of TOC and Cl^- may have been related to the absence of livestock during 1979.

Concentrations of chemical constituents in runoff from the control area were still higher in 1979 than those in runoff from the unstocked grazing area. In the fall of 1979, we analyzed surface vegetation, litter, soil, and manure in the unstocked pasture and control areas. These results suggest that the buildup of vegetational litter on the soil surface in the ungrazed grassland increased the soluble and particulate forms of N and P in leaching water (unpublished data). Several years of no grazing may be necessary before accumulation of surface litter significantly changes runoff water quality.

Bacteriological characteristics of runoff from the ungrazed pasture changed somewhat during 1979 (Table 7). Like values for 1976 through 1978, FC counts in snowmelt runoff in 1979 from the ungrazed pasture area were within recommended water quality criteria. The FC/FS ratio was characteristic of that of cattle. FC and FS counts in rainfall runoff from the ungrazed pasture resembled those in rainfall runoff from the control, although they were somewhat lower. However, FC counts in rainfall runoff from the ungrazed pasture and control area exceeded the recommended water quality criterion (200 organisms per 100 milliliters) in 64 and 84 percent of the samples, respectively. The FC/FS ratio of runoff from both areas was similar (0.028 and 0.035) and characteristic of wildlife. Levels of FC and FS in runoff from the unstocked pasture suggest a relatively large background contribution of feces from wildlife.

Conclusions

Chemical and bacteriological characteristics of seasonally grazed pasture apparently are influenced as much by vegetational cover and wildlife activity as by cattle grazing. Consequently, the concentrations of chemical constituents in runoff from ungrazed grassland were greater than those in runoff from grazed pasture.

Table 6. Chemical characteristics of pasture runoff on an ungrazed test pasture, Clay Center, Nebraska, 1979.

Chemical Constituent	Average Concentrations* (ranges) Ungrazed Pasture	Control Area
	mg/l	
Snowmelt		
$NH_4^+ - N$	0.94 (0.35-2.43)	2.73 (1.62-3.84)
$NO_3^- - N$	0.96 (0.04-2.53)	2.97 (2.29-3.64)
TKN	7.62 (5.34-13.76)	11.32 (9.64-12.99)
Soluble P	1.26 (0.61-2.49)	2.87 (2.09-3.65)
Total P	1.44 (0.66-2.79)	2.98 (2.13-3.82)
TOC	22.1 (15.4-43.6)	27.4 (17.2-37.6)
COD	62.6 (41.0-107.0)	71.0 (48.0-94.0)
Cl^-	4.79 (1.34-13.60)	5.50 (4.30-6.70)
Rainfall†		
$NH_4^+ - N$	0.31 (0.09-0.48)	0.45 (0.23-0.75)
$NO_3^- - N$	0.42 (0.02-0.73)	3.09 (0.09-9.68)
TKN	6.22 (4.10-8.62)	7.96 (4.80-12.10)
Soluble P	0.77 (0.35-1.04)	3.25 (1.71-7.14)
Total P	0.91 (0.50-1.19)	3.54 (3.12-7.59)
TOC	15.0 (9.0-32.7)	29.1 (11.2-52.0)
COD	54.3 (42.0-106.0)	100.2 (72.0-142.0)
Cl^-	1.60 (0.35-5.04)	7.60 (0.72-23.80)

*Values represent arithmetic means.
†See table 2.

The chemical quality of both snowmelt and rainfall runoff from pasture was within water quality criteria in all but one instance. In that case, runoff occurred immediately after pasture fertilization. The quality of pasture runoff was comparable to that from other rotational grazing operations, but considerably better than that from cultivated cropland or urban areas. Three times as much N entered the pasture area in rainfall than left it in runoff.

Cattle grazing resulted in a 5- to 10-fold increase in FC counts in runoff. However, FC (and TC) counts in rainfall runoff from both the grazed pasture and ungrazed control area exceeded water quality criteria (primary and partial body contact) more than 90 percent of the time. Only snowmelt runoff in winter and early spring was within bacteriological standards.

The FC/FS ratio of runoff from both ungrazed grassland and the unstocked grazing area was characteristic of wildlife feces. Thus, fecal contributions from wildlife can have a substantial effect on the bacteriological quality of pasture runoff and probably other nonpoint sources as well. Recommended bacteriological water quality criteria may be inappropriate for characterizing pasture runoff and other nonpoint sources of potential pollution.

Table 7. Summary of bacteriological water quality indicators in runoff from a test pasture, Clay Center, Nebraska, 1979.*

Runoff Type, Indicator	Runoff Characteristics†	
	Ungrazed Pasture	Control Area
Snowmelt		
FC‡	131 (84-202)	-
FS‡	867 (200-2,000)	-
FC/FS ratio	0.282 (0.101-0.535)	
Rainfall		
FC‡	1,640 (10-4,310)	2,960 (15-8,970)
FS‡	52,600 (525-132,000)	100,400 (134,000-205,000)
FC/FS ratio	0.035 (0.019-0.080)	0.028 (0.002-0.066)

*No livestock on pasture since fall of 1978.
†Values represent arithmetic means; values in parentheses represent range for all samples.
‡Bacterial counts expressed as organisms per 100 milliliters.

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